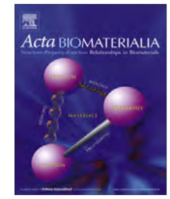
Acta Biomaterialia 8 (2012) 1260–1266

Contents lists available at SciVerse ScienceDirect

Acta Biomaterialia

journal homepage: www.elsevier.com/locate/actabiomat



Real time assessment of surface interactions with a titanium passivation layer by surface plasmon resonance

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ARTICLE INFO

Article history:
Received 31 July 2011
Received in revised form 14 November 2011
Accepted 21 November 2011
Available online 2 December 2011

Keywords:
Titanium passivation layer
Surface plasmon resonance
Protein adsorption
Cell adhesion
Biosensor

ABSTRACT

Due to the high corrosion resistance and strength to density ratio titanium is widely used in industry, and also in a gamut of medical applications. Here we report for the first time on our development of a titanium passivation layer sensor that makes use of surface plasmon resonance (SPR). The deposited titanium metal layer on the sensor was passivated in air, similarly to titanium medical devices. Our "Ti-SPR sensor" enables analysis of biomolecule interactions with the passivated surface of titanium in real time. As a proof of concept, corrosion of a titanium passivation layer exposed to acid was monitored in real time. The Ti-SPR sensor can also accurately measure the time-dependence of protein adsorption onto the titanium passivation layer at sub-nanogram per square millimeter accuracy. Besides such SPR analyses, SPR imaging (SPRI) enables real time assessment of chemical surface processes that occur simultaneously at "multiple independent spots" on the Ti-SPR sensor, such as acid corrosion or adhesion of cells. Our Ti-SPR sensor will therefore be very useful to study titanium corrosion phenomena and biomolecular titanium–surface interactions with application in a broad range of industrial and biomedical fields.

1. Introduction

Thanks to its high strength to density, excellent corrosion resistance, decreasing cost, and increasing availability, titanium and its alloys enjoy widespread industrial applications in a wide variety of highly corrosive environments, including sea water, bleaches, alkaline solutions, oxidizing agents, and organic acids [1]. These excellent properties mean that titanium is widely used in industries including aerospace, marine, power generation, and desalination plants, for instance [2–5]. Its extremely high corrosion resistance results from the formation of a very stable, continuous, highly adherent, and protective oxide film on the titanium surface, formed spontaneously and instantly once fresh metal surfaces are exposed to air or moisture.

Titanium is also commonly used to fabricate a variety of medical devices such as hip and knee joints, bone screws and plates, dental implants, stents, pacemaker cases and centrifugal pumps in artificial hearts [6–8]. Due to rapidly aging populations, especially in developed countries, national health care costs are escalating. In particular, the increased incidence of hard tissue and cardiovascular diseases such as periodontitis, osteoarthritis, and arteriostenosis is strongly correlated with the rapidly growing elderly population. Therefore, the development of innovative treatment techniques for functional repair or complete cure of these diseases is highly desirable. In attempts to improve the healing potential of such medical device, much research has been devoted to titanium surface modification methods that enable controlled adsorption of biomolecules and ions or regulated drug release [9–12]. In biomaterial sciences the strategic importance of fundamental research in nanobiotechnology has recently been acknowledged [13]. The development of highly sensitive methods that can monitor the interaction of biomolecules at titanium surfaces are therefore needed.

Surface plasmon resonance (SPR) can offer real time and label-free analysis of the interfacial events that occur on the surface of a metal layer under physiological conditions [14,15]. Recently, the technique of SPR imaging (SPRI) has been developed and applied to monitor the adsorption of organic materials and biomolecules at multiple independent spots [16]. In this study we report for the first time on our development of a titanium passivation surface sensor chip for SPR [17]. There are few reports of titanium SPR (Ti-SPR) sensors in which the titanium metal layer was passivated

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doi:10.1016/j.actbio.2011.11.025